Effect of non-sinusoidal currents on the acoustic noise excitation of induction motors

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***Abstract*: Current harmonics cannot be completely avoid in induction motors with FOC. Their influence on the acoustic noise has been studied so far by means of analytical or experimental methods. An alternative approach is the combination of analytical and numerical methods. This is here applied to identify the origin of a disturbing frequency-order of the acoustic noise of an induction machine.**

***Keywords*: noise, current harmonics**

I. Introduction

Induction machines operating as servomotor are fed by power converters. Their current harmonics have a detrimental influence on the noise radiated by the machine. This has been studied so far by means of analytical and experimental methods [1]. Analytical methods allow studying systematically the whole chain of effects leading to the generation of noise, from the stator currents to the deformation. Therefore, they are very useful for the identification of cause-and-effect relationships but not for their quantification. On the other hand, experimental methods are more accurate, although also more expensive and unable to prove a causal link between a current harmonic and noise. A combination of analytical and numerical methods is used in this papers to identify the origin of the measured 240-Hz-component of the acoustic noise radiated by an induction machine (14^{th} frequency-order). The analytical model is used to identify the cause of the problem. Coupled FE simulation allows afterwards its quantification. This 14^{th} frequency-order appears as disturbing in the measurements but it cannot be explained without considering the current harmonics. Moreover, the mechanical load presents a resonance in this frequency area.

II. Models

The stator flux-density produced by a non-sinusoidal stator current can be calculated as [2]:

$$B_1(x,t) = \sum_{k=1}^{k=\infty} \sum_{\nu_1=p(6g_1+k)} B_{1,k,\nu_1} \cdot \sin(\nu_1 \cdot x - k \cdot \omega_1 - \phi_k), \quad (1)$$

with p the pole-pair number of the machine, $\nu_1 = p(6g_1 + k)$ the number of pole pairs of each harmonics and $\omega_{\nu_1} = k\omega_1$ the angular speed of the magnetic flux-density wave. Analogously, the rotor harmonics have the pole pair number ν_2 and the angular speed ω_{ν_2},

$$\nu_2 = p + g_2 \cdot N_2,\ g_2 \in \mathbb{Z} \quad (2)$$

$$\omega_{\nu_2} = \omega_1(1 + g_2 \tfrac{N_2}{p}(1-s)), \quad (3)$$

where N_2 is the number of rotor slots and s the slip. Combined with (1), the mode-order r and the angular frequency ω of the main surface forces acting on the stator teeth can be calculated as follows:

$$r = \nu_1 \pm \nu_2 = g_2 \cdot N_2 + 6p \cdot g_1 + p(1 \pm k) \quad (4)$$

$$\omega = \omega_{\nu_1} \pm \omega_{\nu_2} = \omega_1(g_2 \tfrac{N_2}{p}(1-s) + 1 \pm k) \quad (5)$$

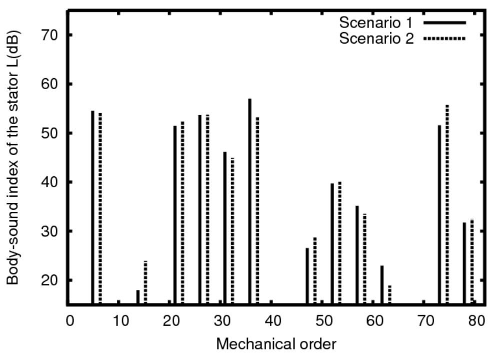

Figure 1. Structure-dynamic behavior of scenarios 1 and 2

The deformation of the stator yoke decreases proportionally with the mode-order of the force excitation. This can be used to identify the critical forces.

For the numerical study of the structure-dynamic behavior of the machine, a 2D transient electromagnetic simulation is coupled weakly with a structure-dynamic harmonic simulation [3]. The mechanical load is not considered. Therefore, its resonance near 280 Hz does not appear in the simulations.

III. Results

First of all, the tables containing the frequency-orders and mode-orders of the surface-force are built using (4) and (5). The frequency-order 14 of the surface-force appears only in the table corresponding to the 4^{th} stator current harmonic ($k = 4$). The smallest emerging mode-order is $r = 4$. This result is being confirmed and quantified through numerical simulation. Two scenarios are simulated. The first one implies a sinusoidal stator current. In the second one, this is perturbed with a 4^{th} harmonic (2% of the value of the fundamental current). Fig. 1 shows the comparision of the simulated values of the body-sound index of the stator [3] for both cases. Although the 14^{th} frequency-order is not very critical in the simulations due to the absence of the resonance of the mechanical load, the value of the body-sound index is significantly increased in presence of a very small 4^{th} stator current harmonic. Further details about the methods and the results will be presented in the full paper.

References

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